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QUANTITATIVE STUDIES ON INSHORE
DIATOMS AND DINOFLAGELLATES OF
THE CALIFORNIA COAST IN 1925

BY

HORACE M. BULEY

QUANTITATIVE STUDIES ON INSHORE
MARINE DIATOMS AND DINOFLAGEL-
LATES TAKEN AT FIVE STATIONS ON
THE EAST PACIFIC COAST IN 1926

BY

DOROTHEA FOX

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QUANTITATIVE STUDIES ON INSHORE DIATOMS AND DINOFLAGELLATES OF THE CALIFORNIA COAST IN 1925

BY

HORACE M. BULEY

INTRODUCTION

This paper constitutes the seventh of a series by the Scripps Institution of Oceanography dealing with the distribution of Pacific Coast diatoms and dinoflagellates. Samples for this year were taken from four stations in California, La Jolla, Oceanside, Pt. Hueneme, Pacific Grove, and one offshore on the Farallone Islands. Catches at the first three stations were made continuously throughout the year, but at Pacific Grove only for the first thirty-four weeks, and at the Farallone Islands after May 1. Methods of collection and study were the same as in preceding years (Allen, 1928).

DIATOMS

SEASONAL DISTRIBUTION

Indications of maximum productivity in spring were found at all five stations, being well marked at La Jolla, Oceanside, and Pt. Hueneme, and less prominent at Pacific Grove and Farallone Islands (table 1 and fig. 1).

The taking of samples was not begun until May 1 at the Farallone Islands, and the first week's average of 22,792 cells per liter is the only one that shows any significant number of diatoms for this station, probably indicating that collection of samples was begun during the decline of a vernal pulse.

Pt. Hueneme showed by far the greatest productivity over the entire year, numbers at this station averaging nearly four times the combined averages of the four other stations. Of the fifty-two week-averages fourteen exceeded 100,000 cells per liter. The highest peak of the year was recorded during the week ending April 22, when 760,000 cells per liter were found. However, in four successive months, June, July, August, and September (table 1 and fig. 1), pulses of comparable height appeared, a regularity of recurrence unusual at any station. The distribution at this station for 1925 is in striking confirmation of the conclusion from the five years' sum-

mary (Allen 1928), that Pt. Hueneme tended to major productivity in the median six months of the year, rather than in the first six months as at La Jolla and Oceanside.

At Oceanside the first pulse of the year occurred during the third week of January when the week's sample yielded 102,060 cells per liter. It was not long sustained and it was not until the week ending May 20 that this station again yielded a sample exceeding 100,000 cells per liter. At that time the abundance of diatoms was greatest of the year at La Jolla, the average recorded being 84,880 cells per liter for the week ending May 20. Although the abundance through July at both stations compared favorably with that of earlier periods the total production for the second half-year was far inferior to that of the first half. However, total production for the median six months was almost as great as that for the first, showing a tendency to resemble distribution at Pt. Hueneme more nearly than had been true of some years. Small increases of abundance, at Oceanside and La Jolla in September, coincided with the conspicuous pulse at Pt. Hueneme, thus showing a feeble response to some condition influential there (table 1 and fig. 1).

As in former years La Jolla and Oceanside showed a strong similarity in their seasonal distribution of diatoms, but the greater abundance at Oceanside at all seasons was unusual, La Jolla having produced superior numbers in three out of four preceding years (Allen 1928b, p. 350).

From the first of October to the end of the year numbers were small at all stations, almost entirely smaller than in any of the preceding five years. This close agreement also indicates the operation of some influence effective in the three localities.

DISTRIBUTION OF SPECIES

SOUTHERN STATIONS

In agreement with the records of previous years the most common genus of diatoms at all stations was *Chaetoceras*. Its principal representative at La Jolla was *Chaetoceras debile* Cl., at Oceanside the catchall group, *Chaetoceras* sp., and at Pt. Hueneme and the Farallones, *C. debile* Cl. Most of its other representatives were of the small ill-defined type difficult to distinguish.

A conspicuous feature at all stations in the production of diatoms for the year was the heavy representation of the single species *Eucampia zoodiacus* Ehr. at Pt. Hueneme where it strongly overshadowed the more constantly represented genus *Chaetoceras*. This numerical dominance was reached through two three-week periods of heavy abundance occurring in the last three weeks of April and the

last three weeks of July. In the April period this species constituted nearly 70 per cent of the diatoms caught and in July over 90 per cent. It was present in the intermediate period, but not prominent at any time other than the two periods of dominance. This showing is strongly confirmatory of earlier information concerning *Eucampia* (Allen, 1928, p. 382) which indicated a tendency toward exclusion of other species at times of great abundance, toward erratic appearance, and toward greater abundance at Pt. Hueneme than at any other station.

DINOFLAGELLATES

SOUTHERN STATIONS

As was the case with the diatoms, Pt. Hueneme also led in the numbers of dinoflagellates (table 2 and fig. 1), showing a total of 86,300 dinoflagellates as against 77,440 for Oceanside, and 34,176 for La Jolla.

The dinoflagellate that appeared in the greatest abundance at all of the stations was *Ceratium furca* (Ehbg.) Cl., and no other dinoflagellate appeared in as many weeks as this species. Its greatest abundance was observed in April. *Prorocentrum micans* Ehrh. held second place in numerical importance in the catches, but, in consideration of the results of experiments in 1929 showing heavy losses of this small species through the filtration net, it may have been the most abundant. At the Farallone Islands and at Pacific Grove dinoflagellates appeared in such small numbers as to possess but little significance.

SUMMARY

Samples for the year 1925 were taken daily from three southern California stations, Pt. Hueneme, Oceanside, and La Jolla; for part of the year from Pacific Grove and the Farallone Islands.

Evidences of both spring and fall pulses were observed at all stations.

Pt. Hueneme showed the greatest productivity of any station both in diatoms and dinoflagellates, with an unusual regularity of occurrence of pulses in the median six months of the year.

La Jolla and Oceanside showed a similarity in distribution but the total numbers were much less at La Jolla than at Oceanside and less at both than in preceding years.

The genus appearing most often was *Chaetoceras*.

Eucampia zoodiacus Ehr. appeared at Pt. Hueneme in large numbers through two three-week periods.

Dinoflagellates were few at all stations throughout the year.

TABLE 1
AVERAGES BY WEEKS OF DIATOMS AT FIVE STATIONS IN 1925

Week ending		Pacific Grove	Pt. Hueneme	Oceanside Pier	La Jolla Pier	Farallone Islands
Jan.	7.....	220	2,280	21,680	960	.....
	14.....	40	3,340	17,660	4,580	.....
	21.....	20	18,500	102,060	15,540	.....
	28.....	140	23,760	33,020	15,460	.....
Feb.	4.....	20	41,120	4,660	7,340	.....
	11.....	120	3,780	6,080	10,160	.....
	18.....	20	1,440	16,320	13,800	.....
	25.....	1,340	2,640	14,040	30,980	.....
Mar.	4.....	280	5,200	7,120	10,540	.....
	11.....	920	7,580	1,320	4,040	.....
	18.....	420	17,500	14,140	20,980	.....
	25.....	5,660	56,820	1,760	5,640	.....
April	1.....	2,420	60,000	740	3,720	.....
	8.....	580	32,880	820	800	.....
	15.....	280	212,570	780	60	.....
	22.....	620	760,000	680	220	.....
May	29.....	1,820	662,940	260	18,760	.....
	6.....	7,020	286,200	280	34,100	22,792
	13.....	8,020	16,340	63,580	51,140	1,606
	20.....	700	15,300	112,980	84,880	176
June	27.....	1,560	13,840	5,660	21,870	154
	3.....	.....	13,560	800	50,112	198
	10.....	1,020	272,370	7,120	8,000	242
	17.....	2,380	326,600	2,500	520	286
July	24.....	10,140	8,640	119,120	3,900	242
	1.....	5,400	1,760	68,500	13,120	968
	8.....	2,700	1,920	57,500	25,920	550
	15.....	40	185,300	30,260	21,660	176
Aug.	22.....	300	303,220	22,440	22,540	.....
	29.....	6,680	402,980	5,440	16,500	110
	5.....	4,040	126,040	260	180	242
	12.....	460	13,060	200	60	2,662
Sept.	19.....	240	9,160	460	—00	44
	26.....	40	196,880	1,560	2,000	88
	2.....	.....	174,340	1,360	640	66
	9.....	.....	29,120	980	940	198
Oct.	16.....	.....	12,480	1,420	1,940	22
	23.....	.....	103,000	2,100	9,340	88
	30.....	.....	312,900	4,580	12,860	44
	7.....	.....	10,240	3,280	5,300	66
Nov.	14.....	.....	1,020	2,060	40	22
	21.....	.....	180	880	320	22
	28.....	.....	40	460	00	00
	4.....	.....	260	260	160	88
Dec.	11.....	.....	1,780	1,580	20	44
	18.....	.....	1,220	9,300	240	00
	25.....	.....	1,400	200	60	00
	2.....	.....	00	80	20	00
Dec.	9.....	.....	00	3,200	20	00
	16.....	.....	420	360	00	.....
	23.....	.....	820	100	80	.....
	30.....	.....	140	00	40	.....

TABLE 2
AVERAGES BY WEEKS OF DINOFLAGELLATES AT FIVE STATIONS IN 1925

Week ending	Pacific Grove	Pt. Hueneme	Oceanside Pier	La Jolla Pier	Farallone Islands
Jan. 7.....	20	540	620	240	.....
14.....	60	1,640	160	160	.....
21.....	20	840	160	220	.....
28.....	00	200	380	460	.....
Feb. 4.....	00	360	220	460	.....
11.....	00	280	700	1,060	.....
18.....	00	580	1,280	1,960	.....
25.....	20	840	1,740	2,160	.....
Mar. 4.....	20	720	1,920	1,600	.....
11.....	00	11,900	1,820	1,000	.....
18.....	20	1,220	1,620	1,620	.....
25.....	40	1,120	8,760	4,560	.....
April 1.....	00	1,400	20,940	1,000	.....
8.....	00	760	4,220	1,060	.....
15.....	00	2,660	1,820	600	.....
22.....	20	420	2,320	440	.....
29.....	00	720	2,320	200	.....
May 6.....	00	2,000	460	140	66
13.....	00	1,660	300	180	00
20.....	00	3,440	1,140	460	00
27.....	00	8,820	80	1,242	00
June 3.....	.....	5,860	280	1,134	00
10.....	00	2,340	920	340	22
17.....	00	2,600	2,760	180	00
24.....	00	1,220	1,200	380	00
July 1.....	00	3,940	780	80	00
8.....	00	4,980	280	420	00
15.....	00	3,820	160	120	00
22.....	00	1,680	260	60	.....
29.....	00	1,040	280	40	22
Aug. 5.....	00	840	360	00	44
12.....	00	700	220	100	22
19.....	00	4,000	460	240	00
26.....	00	900	2,160	260	00
Sept. 2.....	.....	2,580	1,980	220	44
9.....	.....	2,020	900	660	00
16.....	.....	1,780	360	720	22
23.....	.....	640	820	1,460	00
30.....	.....	1,200	1,160	1,000	00
Oct. 7.....	.....	300	1,900	320	00
14.....	.....	520	360	360	00
21.....	.....	220	400	740	00
28.....	.....	180	340	120	00
Nov. 4.....	.....	300	300	300	00
11.....	.....	160	1,940	260	00
18.....	.....	200	320	260	00
25.....	.....	20	2,620	480	00
Dec. 2.....	.....	20	400	1,400	00
9.....	.....	40	200	820	00
16.....	.....	00	220	440	.....
23.....	.....	60	60	300	.....
30.....	.....	20	60	140	.....

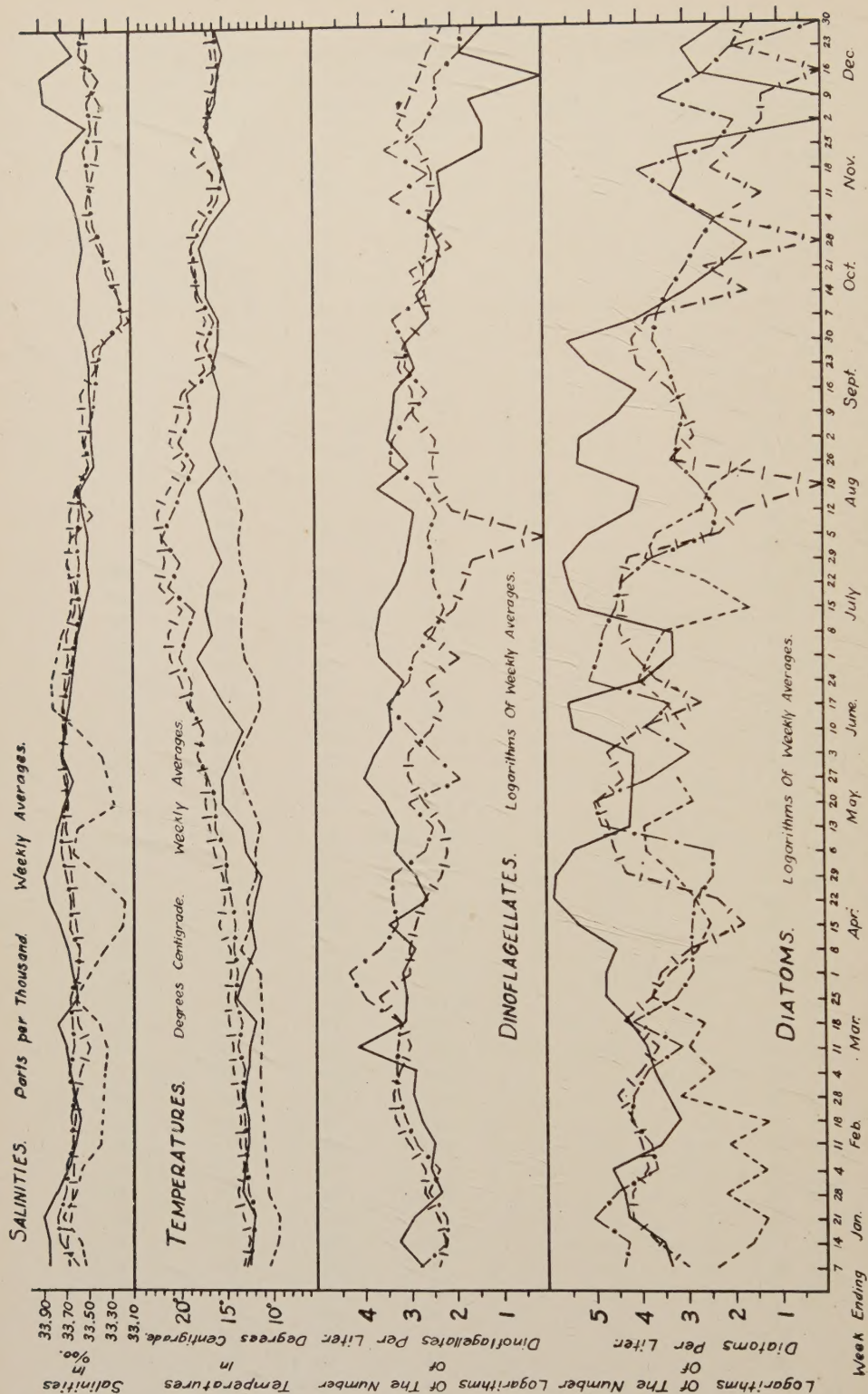


Fig. 1. Graph showing the distribution of diatoms and dinoflagellates at four stations in 1925.
 La Jolla, ———; Oceanside, - - - - -; Pt. Hueneme, - · - · -; Pacific Grove, - - - - -.

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TAKEN AT FIVE STATIONS ON THE
EAST PACIFIC COAST
IN 1926

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BY

DOROTHEA FOX

INTRODUCTION

This paper is the eighth in a series which deals with this subject. It concerns surface material collected at five points inshore along the east Pacific Coast during the year 1926; La Jolla, Lat. $32^{\circ} 52' N$, Long. $117^{\circ} 17' W$; Oceanside, $33^{\circ} 12' N$, Long. $117^{\circ} 22' W$; Pt. Hueneme, Lat. $34^{\circ} 8' N$, Long. $119^{\circ} 12' W$; Farallone Light, Lat. $37^{\circ} 41' N$, Long. $123^{\circ} 0' W$; Scotch Cap, Lat. $54^{\circ} 33' N$, Long. $164^{\circ} 44' W$.

Collections were made every forenoon except Sundays and holidays but not until after January at Farallon Light and after July at Scotch Cap. All collections were made and examined in accordance with the standard method established by the Scripps Institution (Allen, 1922), with the addition that special effort was made to record the condition of the specimens by recording numbers in good and poor condition with different-colored pencils, and estimating totals separately for statement of condition. At La Jolla, Oceanside and Pt. Hueneme seven gallons of water were filtered. Because of difficulty in making collections from the rocks, three gallons only were filtered at Farallone Light. Five gallons were filtered at Scotch Cap.

DIATOMS

The diatom catches for all five stations were extremely small, by far the majority consisting of less than one thousand cells to the liter (table 1 and fig. 1). Many fell to less than one hundred cells to the liter and six catches showed no record whatever of diatoms. These six were from Farallone Light. Only eleven weekly averages from the entire series exceeded ten thousand cells to the liter. Of these eleven catches ten were from Pt. Hueneme, and one from La Jolla. The maximum for the year, at Pt. Hueneme, was 258,640 cells to the liter (fig. 1 and table 1). Records from three stations (La Jolla, Oceanside, and Point Hueneme) show that in previous years numbers

TABLE 1
AVERAGE NUMBER OF CELLS PER LITER IN SUCCESSIVE SEVEN-DAY PERIODS
AT PIERS IN 1926

No. of	Week ending	Diatoms				
		La Jolla	Ocean-side	Pt. Hueneme	Farallone Light	Scotch Cap
1	Jan. 7.....	240	1,480	120	.....	.....
2	14.....	940	1,720	220	.....	.....
3	21.....	3,380	200	200	.....	.....
4	28.....	3,260	160	780	200	.....
5	Feb. 4.....	2,240	820	540	200	.....
6	11.....	1,440	40	760	50	.....
7	18.....	1,140	640	980	200	.....
8	25.....	620	1,300	280	0	.....
9	Mar. 3.....	120	320	480	150	.....
10	10.....	360	1,860	.....	150	.....
11	17.....	1,480	940	3,600	200	.....
12	24.....	2,820	2,460	18,180	300	.....
13	31.....	1,560	560	3,980	0	.....
14	April 7.....	1,540	140	360	50	.....
15	14.....	600	220	660	300	.....
16	21.....	480	700	460	250	.....
17	28.....	40	100	200	150	.....
18	May 5.....	80	280	360	100	.....
19	12.....	400	600	7,120	500	.....
20	19.....	260	240	258,640	550	.....
21	26.....	120	320	43,000	1,850	.....
22	June 2.....	60	680	11,800	1,700	.....
23	9.....	60	2,180	480	350	.....
24	16.....	460	340	1,860	450	.....
25	23.....	620	800	34,220	300	.....
26	30.....	1,880	1,800	72,920	1,400	.....
27	July 7.....	10,220	8,580	49,340	4,650	.....
28	14.....	5,440	8,060	93,340	1,000	.....
29	21.....	780	840	44,140	600	.....
30	28.....	780	880	2,910	50	.....
31	Aug. 4.....	280	160	280	50	7,163
32	11.....	480	360	220	50	8,961
33	18.....	180	600	3,480	300	2,784
34	25.....	200	400	660	50	2,755
35	Sept. 1.....	380	160	1,340	0	4,640
36	8.....	80	240	360	50	5,684
37	15.....	260	700	5,300	50	4,205
38	22.....	140	500	6,880	150	1,421
39	29.....	200	440	1,740	100	1,131
40	Oct. 6.....	320	300	280	50	1,073
41	13.....	60	220	1,080	50	725
42	20.....	80	440	7,700	0	2,320
43	27.....	280	720	16,720	100	1,421
44	Nov. 3.....	400	1,860	7,580	50	2,726
45	10.....	740	2,580	2,440	50	2,610
46	17.....	600	420	780	50	2,291
47	24.....	240	180	300	150	3,161
48	Dec. 1.....	80	360	380	0	2,890
49	8.....	240	.....	460	50	2,059
50	15.....	360	160	420	0	1,727
51	22.....	380	40	360	150	322
52	29.....	360	160	440	50	290

of diatoms had been much larger than they were in 1926 (Allen 1922, 1927a and b, 1928a and b, Dorman 1927, Buley 1929). This indicates that 1926 was a year of exceptionally low production, although the counting sheets for 1926 show that by far the majority of cells were in good condition.

GEOGRAPHIC DISTRIBUTION

Although the numbers at Pt. Hueneme were not large they were greatly superior to those at any other California station, thus maintaining a definite lead for the fourth successive year. Its total for 1926 was more than six times as great as the combined totals of La Jolla and Oceanside (table 1 and fig. 1). However, this total was considerably less than that for any one of the six preceding years, thus agreeing with other stations in indicating an exceptionally poor year for diatoms.

The difference in species prominent at the three southern California stations was somewhat greater than in other years, two species ordinarily rare, *Hemiaulus hauckii* Grun. and *Thalassiothrix frauenfeldii* (Grun.) taking the lead in numbers at La Jolla, and the second of these two taking the lead at Oceanside, while *Chaetoceras debile* Cl., and a catchall group of small, indistinctly marked forms of the same genus, led in numbers at Point Hueneme.

The amazing smallness of numbers (absolute and relative) of species and individuals of the genus *Chaetoceras* at La Jolla and Oceanside constitutes an outstanding feature in the distribution of diatoms in southern California in 1926. Through several years this genus had held a leading position, and in most years at all southern California stations its numbers had been considerable or large. The poor showing of these two stations for the year seems to have been due primarily to failure of this particular genus.

Furthermore, the fact that *Hemiaulus* and *Thalassiothrix* appeared in unusual quantities suggests the possibility that the conditions adverse for *Chaetoceras* and less detrimental (or even favorable) to certain other forms were such as would be effective mainly through slight differences in functional requirements of different types and that probably they were chemical.

Hemiaulus was numerically dominant in surface collections as far offshore as San Nicolas Island (about seventy miles) early in the year, and *Thalassiothrix* was numerically dominant in subsurface collections off La Jolla in midyear. The latter was also prominent in Santa Barbara Channel (Station D 65) in August. (For all three of these points see Allen 1928a.) With positive evidence that these species were abnormally prominent over such large areas it seems necessary

to assume that the responsible causes were either widely distributed or so remotely situated that their effects were diffused over regions of indefinite extent.

Numbers at the Farallone Islands were not notably different from those of the preceding year, when they were also very small. For this station it seems probable that distance from land tends to keep numbers small irrespective of differences in years observable at more productive stations inshore. Sedentary forms dislodged from the rocks at the collecting point constituted large parts of the catches.

At Scotch Cap, in the Aleutian Islands, numbers were fairly uniform in the successive weeks of the five months after collecting was begun, but they were not large. However, they were greater than those at La Jolla and Oceanside and compared favorably with those at Pt. Hueneme for the same period. The genera *Skeletonema* and *Leptocylinthus* were more prominent than at the California stations.

SEASONAL DISTRIBUTION

At no station except Pt. Hueneme were there any very strong evidences of seasonal differences in numbers (table 1). At that station the greater abundance at the middle of the year is striking, both in regard to size of weekly averages and in regard to maintenance of such numbers over periods of considerable length. The Farallones indicated a similar tendency, observable in spite of the small numbers. At La Jolla and Oceanside small pulses in March and July coincided with pulses at Pt. Hueneme, but at both stations, the second quarter, which was most productive at Pt. Hueneme, barely escaped being least productive.

La Jolla was the only station showing a very marked difference in the species or genera prominent in different seasons, *Hemiaulus* leading in the first quarter and *Thalassiothrix* in the third. At Point Hueneme *Chaetoceras* held the lead in the periods of increased abundance and through most of the year.

DINOFLAGELLATES

Numbers of dinoflagellates were small at all stations (table 2), practically non-existent at the Farallones, very few at Scotch Cap, and at no time very considerable at either La Jolla or Oceanside. At Pt. Hueneme moderate numbers were steadily maintained through most of the middle two quarters of the year, showing slight pulses at the time of May and July pulses of diatoms. At La Jolla four small pulses were observable, the last one extending from mid-September to mid-November, and there were three of similar magnitude but small extent at Oceanside.

TABLE 2
AVERAGE NUMBERS OF CELLS PER LITER IN SUCCESSIVE SEVEN-DAY PERIODS
AT PIERS IN 1926

No. of	Week ending	Dinoflagellates				
		La Jolla	Ocean- side	Pt. Hueneme	Farallone Light	Scotch Cap
1	Jan. 7.....	40	0	80		
2	14.....	20	0	60		
3	21.....	100	20	60		
4	28.....	120	40	60	50	
5	Feb. 4.....	120	0	20	0	
6	11.....	60	0	100	0	
7	18.....	120	20	40	0	
8	25.....	60	60	40	0	
9	Mar. 3.....	80	20	20	0	
10	10.....	60	20		00	
11	17.....	100	20	40	0	
12	24.....	380	100	180	0	
13	31.....	340	80	540	0	
14	April 7.....	460	40	280	0	
15	14.....	2,280	460	720	0	
16	21.....	2,320	1,160	5,940	0	
17	28.....	340	200	8,500	50	
18	May 5.....	240	260	11,300	0	
19	12.....	320	160	2,320	0	
20	19.....	500	220	5,520	0	
21	26.....	320	120	1,660	0	
22	June 2.....	180	120	1,220	0	
23	9.....	1,100	100	1,440	0	
24	16.....	1,520	360	7,500	0	
25	23.....	400	220	3,440	0	
26	30.....	300	420	2,360	0	
27	July 7.....	460	540	8,400	0	
28	14.....	940	540	14,060	0	
29	21.....	540	440	7,580	0	
30	28.....	640	40	740	0	
31	Aug. 4.....	480	180	480	0	29
32	11.....	300	20	1,660	0	116
33	18.....	660	1,020	1,120	0	87
34	25.....	600	540	360	0	116
35	Sept. 1.....	1,360	280	560	0	87
36	8.....	560	480	1,280	0	406
37	15.....	820	700	1,020	50	174
38	22.....	1,120	1,160	240	0	348
39	29.....	1,500	1,080	320	50	203
40	Oct. 6.....	1,800	680	140	0	58
41	13.....	1,120	660	1,380	0	406
42	20.....	1,860	560	1,740	0	261
43	27.....	2,240	920	2,040	0	291
44	Nov. 3.....	1,640	220	760	0	145
45	10.....	1,220	300	340	0	29
46	17.....	760	60	40	0	29
47	24.....	860	20	60	0	29
48	Dec. 1.....	520	60	40	0	145
49	8.....	240		0	0	29
50	15.....	240	20	40	0	87
51	22.....	220	0	0	0	29
52	29.....	60	0	20	0	58

However, similarly small numbers of dinoflagellates had been recorded from the three southern California stations in other years and in no year had the numbers been nearly so large as those frequently reached by diatoms. Therefore, while the record was not very good for dinoflagellates it was not so exceptionally poor as the record for diatoms.

Gonyaulax polyedra Stein was more prominent at Pt. Hueneme than it had been for some years, and *Peridinium crassipes* Kof. and *Dinophysis caudata* Kent were more prominent at La Jolla than usual, but the numbers representing them were not especially notable. In so far as their prominence represented a change from the usual prominence of *Prorocentrum micans* Ehr., *Ceratium furca* (Ehr.), and *C. tripos* (O. F. M.), it may have significance similar to that of *Hemiaulus* and *Thalassiothrix* in indicating influences most successfully met by certain species not usually leaders.

CONCLUSIONS

1. Production was poor at all California stations. This was most distinctly true at La Jolla and Oceanside as compared with preceding years, and the relative deficiency was greater for diatoms than it was for dinoflagellates.

2. The numerical deficiency coupled with the prominence of genera ordinarily obscure as shown over a wide area indicated the operation of exceptional influences over the southern California region.

3. This was the fourth successive year in which Pt. Hueneme yielded distinctly higher numbers of diatoms than any other station.

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